ORIGINAL PAPER

CHROMIUM BIOACCUMULATION FROM COMPOSTS AND VERMICOMPOSTS BASED ON TANNERY SLUDGES

BIOAKUMULACJA CHROMU Z KOMPOSTÓW I WERMIKOMPOSTÓW Z OSADÓW GARBARSKICH

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ABSTRACT

Storage of waste substances is not indifferent to ecological equilibrium in the environment therefore should not be the ultimate way to limit waste arduousness. Therefore, the conducted investigations aimed to determine the effect of tannery composts and vermicomposts loaded with chromium on this element bioaccumulation in earthworm bodies and biomass of selected plants. Chromium in composts and vermicomposts based on tannery sludges occurred in small quantities and easily soluble compounds. Chromium concentrations in redworm biomass points to this metal accumulation in Eisenia fetida body tissues. This element content in redworm biomass was significantly positively correlated with its content in composts. Chromium content in plants was diversified and on treatments was generally smaller than on mineral treatment or farmyard manure. Chromium absorbed by plants was stored mainly in the root systems, and over the norm content of this element found in vermicomposts did not cause its excessive accumulation in plant biomass.

KEY WORDS: chromium, compost, vermicompost, Eisenia fetida, plants

DETAILED ABSTRACT

Celem przeprowadzonych badań było określenie wpływu kompostów i wemikompostów pochodzenia garbarskiego obciążonych chromem na bioakumulację tego pierwiastka w ciele dżdżownic i biomasie wybranych roślin. Materiałem wyjściowym do badań były komposty sporządzone na bazie osadu garbarskiego pochodzącego z mechaniczo-biologicznej oczyszczalni ścieków garbarskich. Komposty sporządzono z następujących komponentów: osad garbarski z dodatkiem trocin drzew iglastych, osad garbarski z dodatkiem kartonu oraz osad garbarski z dodatkiem słomy pszennej. Dodatek poszczególnych materiałów stanowił 15% w stosunku do suchej masy osadu. Czas kompostowania wynosił 12 miesięcy, po czym komposty zostały zasiedlone dżdżownicami. Do każdego kompostu oraz podłoża kontrolnego (obornik) wpuszczono po 100 dojrzałych płciowo osobników Eisenia fetida. W warunkach laboratoryjnych oceniono wpływ procesu kompostowania i wermikompostowania na zawartość mobilnych form chromu. Formy mobilne chromu oznaczono po ekstrakcji wodą redestylowaną, a następnie roztworem $CaCl_2$ o stężeniu 0,05 mol·dm^{-3}. W warunkach doświadczenia wazonowego badano wpływ uzyskanych wermikompostów na zawartość chromu w wybranych roślinach. Doświadczenie obejmowało siedem obiektów (w czterech powtórzeniach): A-kontrola (bez nawożenia); B-nawożenie mineralne; C-obornik; D-osad garbarski nieprzetworzony; E-wermikompost (osad garbarski + trociny); F-wermikompost (osad garbarski + karton); G-wermikompost (osad garbarski + słoma). Uzyskane wyniki badań poddano ocenie statystycznej. Dla plonów roślin i zawartości chromu w biomasie wykonano jednoczynnikową analizę wariancji, a istotność różnic pomiędzy średnimi arytmetycznymi oszacowano za pomocą testu t-Studenta. Dla pozostałych oznaczeń obliczono odchylenie standardowe (SD) oraz udział odchylenie standardowego w średniej (V%). Wartość współczynnika korelacji dla zawartości chromu w podłożach i jego koncentracji w ciele dżdżownic wyliczono według testu nieparametrycznego Spearmana przy poziomie istotności $p < 0,05$. Chrom w kompostach i wermikompostach z osadów garbarskich występował w niewielkich ilościach w związkach łatwo rozpuszczalnych. Zawartość chromu w biomasie dżdżownic wskazuje na akumulację tego metalu w tkankach ciała Eisenia fetida. Zawartość tego pierwiastka w biomasie dżdżownic była istotnie dodatnio skorelowana z jego zawartością w kompostach. Zawartość chromu w roślinach była zróżnicowana, a w obiektach z wermikompostami z reguły mniejsza niż w obiekcie z nawożeniem mineralnym i obornikiem. Chrom pobrany przez rośliny był przez nie gromadzony głównie w systemach korzeniowych, a ponadnormatywna zawartość tego pierwiastka stwierdzona w wermikompostach nie spowodowała jego nadmiernej kumulacji w biomasie roślin.

KEY WORDS: chrom, kompost, wermikompost, Eisenia fetida, rośliny

INTRODUCTION

Changes which occur in soil environment and are connected with its pollution are not neutral for soil flora or fauna, including earthworms. Research conducted so far has demonstrated that earthworms tolerate high concentrations of some toxic substances, including heavy metals in the substratum [16, 17, 21, 22, 25, 33]. Various mechanisms are responsible for this [5, 8]. Earthworm ability to accumulate considerable amounts of heavy metals may pose a hazard for the subsequent links of food chain – mammals and birds for which earthworm are important dietary component.

The problem of toxicity and accumulation of heavy metals in earthworm bodies has been investigated many times, including even potential use of these organisms for cleaning soils contaminated with these elements. However, the assumed effect has not been reached because as each living organism, also earthworms have certain limited abilities for harmful substances storage, moreover the problem of their subsequent utilisation has not been solved, either [32].

The other investigations on the use of earthworms have been focused on testing their potential utilisation for biological transformation of waste materials, including sewage sludges. Industrial sewage sludges have posed a serious problem, which so far has not been solved. This group comprises also tannery sludges, frequently excessively overloaded with chromium, which makes their environmental application impossible. Potential accumulation of excessive quantities of chromium in soil resulting from these materials application may in effect lead to its contamination [36]. However, it does not exclude a necessity to seek solutions enabling these materials management. One of the possibilities is biological transformation of wastes using Eisenia fetida redworm [16, 26, 29]. Application of redworms for processing sewage sludges is little effective. However, it becomes very important when sewage sludges are initially composted with plant mass or other organic components [34], which allows for fast and effective transformation of compost properties and obtaining useful fertilizers, so called vermicomposts. The use of redworm for processing sewage sludges increases the content of nutrients easily assimilable for plants in a vermicompost, which affects better quality of plant biomass and limits pathogenicity of some bacteria and fungal diseases [1].

So far only few authors have undertaken research to assess the effect of vermicomposts obtained from sewage sludges on heavy metal accumulation in plants, whereas studies on vermicomposts from tannery sludges have been even fewer [9, 10]. Plants are the most important link of food chain on the way of heavy metal translocation from soil to plants, animal and human organisms [11]. Phytoavailability of individual elements in soil is determined by numerous factors, mainly element concentrations in soil solution, their interrelations, but also sorption processes occurring in soil. Another important factor influencing heavy metal phytoavailability are plant abilities as such for absorbing metals but also specific properties of the elements [3, 28]. Plant fertilization, mainly with organic materials prepared on the basis of waste materials, in which heavy metal bioavailability may change due to their transformations is also important.

Storage of waste substances is not indifferent to ecological equilibrium in the environment therefore should not be the ultimate way to limit waste arduousness. Therefore, the conducted investigations aimed to determine the effect of tannery composts and vermicomposts, loaded with chromium on this element bioaccumulation in earthworm bodies and biomass of selected plants.

MATERIAL AND METHODS

Initial material for the research were composts prepared on the basis of tannery sludge originating from mechanical-biological tannery sludge treatment plant. The composts were produced from the following components: tannery sludge with coniferous trees' sawdust, tannery sludge with a supplement of cardboard and tannery sludge with wheat straw admixture. Additions of individual materials constituted 15% in relation to sludge dry matter. Composting time was 12 months and the composts were settled with redworms. Each compost and control medium (farmyard manure) received 100 sexually mature Eisenia fetida redworms. Vermicomposting was carried out in PCV containers with 20 dm^3 of materials at the mass moisture 75%. After six months 10 redworms from the redworm population were selected for analysis from each vermicompost. Washed and then weighed and anesthetized redworms were wet mineralized in a mixture of concentrated HNO_3 and $HClO_4$ acids in 2:1 ratio.

In laboratory, the effect of composting and vermicomposting process on mobile chromium form concentrations was assessed. In dried (at 70^{o}C) and ground materials total chromium content was assessed after sample mineralization in a muffle furnace (at 450^{o}C for 5hrs) and dissolving the remains in a diluted nitric acid (1:2). In solutions obtained after redworm biomass and organic materials mineralization, chromium concentrations were assessed with AAS method in PU 9100X Philips apparatus [2].

Mobile forms of chromium were determined after extraction with redistilled water and then with 0.05

Table 1. Chemical composition of farmyard manure and organic materials

Determination	FYM	Tannery sludge (unprocessed)	Vermicompost (tannery sludge + sawdust)	Vermicompost (tannery sludge + cardboard)	Vermicopost (tannery sludge + straw)
Dry matter $g \cdot kg^{-1}$	269	239	420	396	386
			$g \cdot kg^{-1}$ of dry matter		
Organic C	313	305	137	126	144
Total N	25.4	38.2	26.3	26.6	27.7
P	6.9	3.3	7.9	7.0	11.1
K	13.0	4.9	2.1	1.6	2.4
Ca	21	80	127	134	128
Mg	6.4	2.4	3.5	3.2	3.1
Na	1.2	2.2	4.2	3.2	2.0
			$mg \cdot kg^{-1}$ of dry matter		
Cu	146	20	50	44	43
Zn	460	108	405	329	341
Ni	10.0	55.0	21.1	17.3	18.9
Pb	15	16	48	42	42
Cd	2.10	0.20	0.94	0.66	0.81

Table 2. Content of chromium in farmyard manure and organic materials

Materials	Total content*	Cr - H_2O**	Cr - $CaCl_2$**
Farmyard manure (FYM)	11.1	0.10 0.90	0.32 2.88
Compost (tannery sludge + sawdust)	6917	33.30 0.48	15.56 0.22
Compost (tannery sludge + cardboard)	6935	38.32 0.55	10.52 0.15
Compost (tannery sludge + straw)	7216	35.71 0.49	16.19 0.22
Vermicompost (tannery sludge + sawdust)	7937	25.12 0.32	5.97 0.07
Vermicompost (tannery sludge + cardboard)	8261	17.00 0.21	3.56 0.04
Vermicompost (tannery sludge + straw)	7545	17.04 0.22	6.96 0.09
SD	549	9.41	5.22
VC%	7	34	53

* - $mg \cdot kg^{-1}$ air-dry mass of material; ** - $mg \cdot kg^{-1}$ absolutely dry mass; numerator: $mg \cdot kg^{-1}$; denominator: % of total content

Table 3. Total yields dry matter of plants ($g \cdot pot^{-1}$)

	Treatment	Parts of plants		Total yields
		Top parts	Roots	
Soil with addition of	Control (no fertilisation)	68.4	8.5	76.8
	Mineral fertilization	333.4	39.7	373.1
	FYM	276.7	28.2	304.9
	Tannery sludge (unprocessed)	280.3	28.3	308.5
	Vermicompost (tann. sludge + sawdust)	297.0	31.3	328.3
	Vermicompost (tann. sludge + cardboard)	314.3	34.5	348.8
	Vermicompost (tann. sludge + straw)	291.4	32.8	324.2
	$LSD_{p<0.05}$	3.96	0.73	2.67

$mol \cdot dm^{-3}$ $CaCl_2$ solution according to McLaren and Crowford method modified by Bogacz [4]. Chromium content in the obtained extracts was assessed with ICP-AES method in JY Ultrace 238 apparatus.

The pot experiment tested the effect of obtained vermicomposts on chromium concentrations in selected plants. The experiment was conducted in a vegetation hall in PCV pots with 5 kg of air-dried soil material. The soil material used for the experiment was characterized by pH = 4.11 (measured in 1 $mol \cdot dm^{-3}$ KCl solution) and 27% content of granular size fraction < 0.002 mm. Hydrolytic acidity determined with Kappen method was 73.4 $mmol(+) \cdot kg^{-1}$, total nitrogen – 1.90 $g \cdot kg^{-1}$, and organic carbon concentration 14.1 $g \cdot kg^{-1}$ of soil material dry matter [31].

The experiment comprised seven treatments in four replications: A - control (without fertilization; B - mineral fertilization; C -farmyard manure; D - unprocessed tannery sludge; E - vermicompost (tannery sludge + sawdust); F - vermicompost (tannery sludge + cardboard); G - vermicompost (tannery sludge + straw). Detailed characteristics of organic materials used for the experiment was given in table 1. Divergences concerning chromium content in unprocessed sludge and vermicomposts resulted from various dates of sludge sampling for composting and vegetation studies. The assumed dose of organic materials equalled 1.0 $g \cdot pot^{-1}$. Phosphorus fertilization was dosed 0.6 g, whereas potassium 1.2 $g \cdot pot^{-1}$. Nitrogen fertilization on mineral treatment was applied as NH_4NO_3 solution, supplementary phosphorus fertilization in the form of $Ca(H_2PO_4)_2 \cdot H_2O$ and potassium as KCl. Maize, KLG 2210 c.v. was cultivated in the first year of the experiment and in the subsequent years winter rape 'Górczański' c.v with the same mineral fertilization (1 g N and 1.2 g $K \cdot pot^{-1}$). The

Table 4. Values of tolerance indices (Ti) for plants cultivated in experiment

	Treatment	Maize – 1st year		
		Cob	Steam + leaves	Roots
Soil with addition of	Control (no fertilization)	-*	0.25	0.17
	FYM	0.17	0.70	0.49
	Tannery sludge (unprocessed)	0.19	0.70	0.46
	Vermicompost (tann. sludge + sawdust)	0.37	0.76	0.58
	Vermicompost (tann. sludge + cardboard)	0.25	0.84	0.67
	Vermicompost (tann. sludge + straw)	0.23	0.72	0.60
SD		0.08	0.21	0.18
VC%		32	32	36
	Treatment	Rape – 2nd year		
		Top parts		Roots
Soil with addition of	Control (no fertilization)	0.24		0.33
	FYM	1.07		0.97
	Tannery sludge (unprocessed)	1.19		1.09
	Vermicompost (tann. sludge + sawdust)	1.19		1.06
	Vermicompost (tann. sludge + cardboard)	1.23		1.01
	Vermicompost (tann. sludge + straw)	1.19		1.11
SD		0.39		0.30
VC%		38		32
	Treatment	Sunflower – 2nd year		
		Top parts		Roots
Soil with addition of	Control (no fertilization)	0.17		0.21
	FYM	1.15		1.16
	Tannery sludge (unprocesed)	1.11		0.96
	Vermicompost (tann. sludge + sawdust)	1.16		1.09
	Vermicompost (tann. sludge + cardboard)	1.21		1.29
	Vermicompost (tann. sludge + straw)	1.23		1.22
SD		0.41		0.40
VC%		41		40
	Treatment	Oat – 3rd year		
		Grain	Straw	Roots
Soil with addition of	Control (no fertilization)	0.16	0.22	0.22
	FYM	1.04	1.04	1.02
	Tannery sludge (unprocessed)	1.10	0.99	1.12
	Vermicompost (tann. sludge + sawdust)	1.05	1.03	1.08
	Vermicompost (tann. sludge + cardboard)	1.14	1.09	1.27
	Vermicompost (tann. sludge + straw)	1.05	1.03	1.14
SD		0.38	0.33	0.38
VC%		41	37	39

* absent of yield

second plant cultivated in the same year was sunflower, Lech c.v. fertilized with only 0.5 g N per pot. In the third year of the experiment, oats, Dragon c.v. was grown with supplementary fertilization (0.5 g N and 1.0 g K·pot^{-1}).

Following plant material dry mineralization in a dryer with hot air flow (at 70^{o}C), chromium content was assessed in it after sample mineralization in a muffle furnace (at 450^{o}C for 5 hours) and dissolving the ashes in diluted nitric acid (1:2). In solutions prepared in this way chromium was assessed with ICP-AES method in JY 238 Ultrace apparatus [31].

On the basis of obtained results tolerance index was computed as a ratio of plant yield dry mass on vermicompost to mineral treatments and the contamination degree index (C) as a quotient of chromium concentrations in plant fertilized with vermicomposts and receiving mineral fertilization [23].

The obtained results were subjected to statistical estimation. ANOVA analysis was conducted for plant yields and biomass concentrations in chromium and the significance of differences between arithmetic means was estimated using t-Student test [35]. Standard deviation (SD) was computed for other assessments and the share of standard deviation in mean (VC%). Value of correlation coefficient for chromium content in substrata and its concentrations in redworm bodies were computed by non-parametrical Spearman test on significance level $p < 0.05$. All chemical analyses were considered reliable if relative standard deviation (RSD) estimated for two replications did not exceed 5%.

RESULTS AND DISCUSSION

Easy reduction of Cr^{6+} to Cr^{3+} in soil environment causes that it is generally hardly available to plants [18]. A similar situation concerns tannery sludges [7]. Relatively high total content of this element in the analyzed organic materials is not equal to its full bioavailability. The process of biological transformation (vermicomposting) of prepared composts caused an increase in total forms of chromium, which resulted form condensation of mineral components due to organic substance depletion in result of redworm feeding.

Table 5. Content of chromium in plants cultivated in experiment ($mg \cdot kg^{-1}$ d.m.)

	Treatment	Maize – 1st year		
		Cob	Steam + leaves	Roots
Soil with addition of	Control (no fertilization)	-*	0.39	3.91
	Mineral fertilization	0.15	0.29	3.86
	FYM	0.11	0.35	4.63
	Tannery sludge (unprocessed)	0.14	0.23	5.75
	Vermicompost (tann. sludge + sawdust)	0.13	0.42	7.55
	Vermicompost (tann. sludge + cardboard)	0.10	0.19	7.95
	Vermicompost (tann. sludge + straw)	0.09	0.73	6.71
	$LSD_{p<0.05}$	0.02	0.09	1.10
	Treatment	Winter rape – 2nd year		
		Top parts		Roots
Soil with addition of	Control (no fertilization)	0.76		1.34
	Mineral fertilization	2.23		0.94
	FYM	1.44		1.17
	Tannery sludge (unprocessed)	0.66		2.69
	Vermicompost (tann. sludge + sawdust)	0.61		2.07
	Vermicompost (tann. sludge + cardboard)	0.35		1.89
	Vermicompost (tann. sludge + straw)	0.25		1.52
	$LSD_{p<0.05}$	0.31		0.55
	Treatment	Sunflower – 2nd year		
		Top parts		Roots
Soil with addition of	Control (no fertilization)	2.18		3.78
	Mineral fertilization	0.45		1.32
	FYM	0.44		1.30
	Tannery sludge (unprocessed)	0.46		1.51
	Vermicompost (tann. sludge + sawdust)	0.34		2.33
	Vermicompost (tann. sludge + cardboard)	0.36		1.62
	Vermicompost (tann. sludge + straw)	0.37		1.27
	$LSD_{p<0.05}$	0.08		0.30
	Treatment	Oat – 3rd year		
		Grain	Straw	Roots
Soil with addition of	Control (no fertilization)	0.18	0.54	0.61
	Mineral fertilization	0.19	0.55	2.63
	FYM	0.20	0.52	1.78
	Tannery sludge (unprocessed)	0.23	0.64	8.39
	Vermicompost (tann. sludge + sawdust)	0.20	0.72	4.74
	Vermicompost (tann. sludge + cardboard)	0.26	0.64	4.60
	Vermicompost (tann. sludge + straw)	0.27	0.64	4.60
	$LSD_{p<0.05}$	0.04	0.07	1.16

* absent of yield

The greatest amounts of water extracted chromium were assessed in compost where tannery sludge was mixed with cardboard (Table 2). A decline in water extracted chromium was noted in result of vermicomposting. Irrespective of the added substance (sawdust, cardboard or straw) both in composts and vermicomposts between twice and over four times less chromium extracted by 0.05 mol·dm^{-3} $CaCl_2$ solution was assessed. The share of chromium extracted by this solution in total content was small (0.04 - 0.22%). The obtained results have been corroborated by these reported by Czekała et al [7], which reveal that both in tannery sludge and composts with this sludge supplement chromium occurred in water soluble and exchangeable fraction. Also Kabata-Pendias et al [20] found a small amount of mobile chromium forms in sewage sludge.

Chromium occurrence in animal organisms is highly diversified and primarily depends on animal species and kinds of tissues [19]. Relatively few experiments conducted so far on toxic effect of heavy metals on redworms makes discussion of the obtained results difficult but points to a necessity of their continuation. Chromium concentrations in redworm bodies from the control substratum after the experiment completion was 14 mg·kg^{-1} of fresh mass, whereas almost between 13 and 20 times higher concentrations of this metal were assessed in biomass of redworm feeding on composts from tannery sludges (Figure 1).Such high chromium content in redworm bodies points to its free uptake by these organisms. A significant effect of the content of chromium from composts on this metal level in redworm bodies has been confirmed by correlation coefficient (r = 0.94; p < 0.05). According to Kostecka [27] sewage sludges may provide a good medium for redworms. It might be connected with constantly increasing number of bacteria and protozoans due to sludge treatment. The obstacle to utilization of these wastes as a medium may be not only too high concentration of heavy metals but also insufficient amount of cellulose [15]. According to Malecki et al [30] Eisenia fetida tolerates relatively great contents of heavy metals in the substratum, Hartenstein et al [14] in their studies conducted on sewage sludge substrata found that chromium, even in high concentrations, is not harmful for redworm growth.

Summary amounts of biomass of plants grown in the subsequent years of the experiment were compiled in Table 3. The largest quantity of the aboveground part biomass was registered on treatment where mineral salts NPK (333.4 g·pot^{-1}) were applied. Significantly more (by over 7%) of the aboveground plant part biomass, as compared with the FYM treatment, was obtained on the soil with vermicompost admixture (tannery sludge +

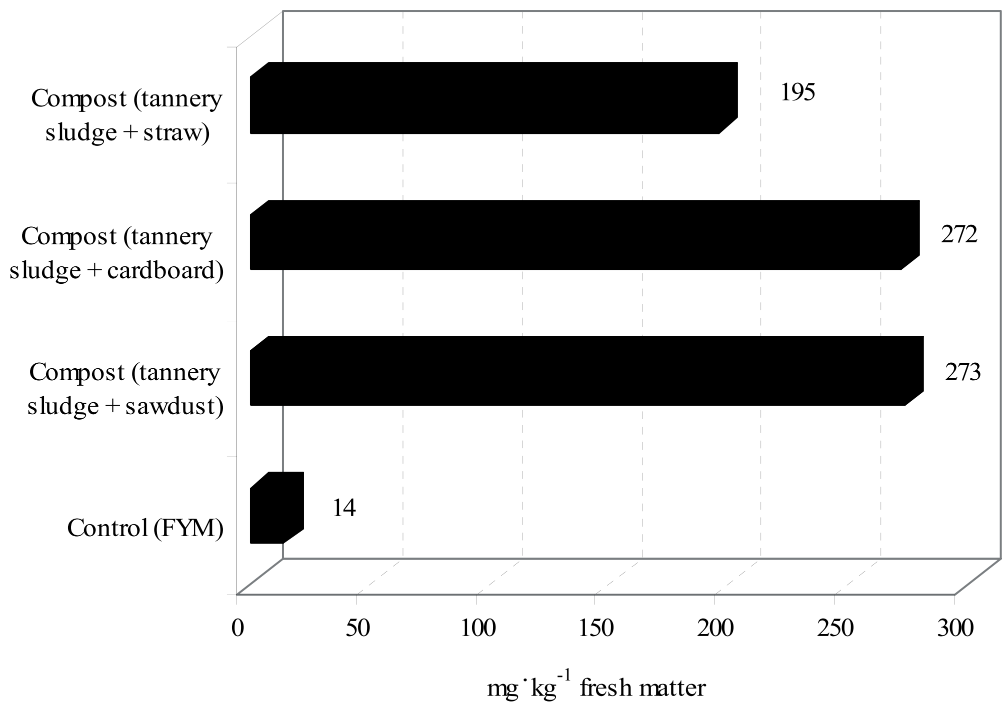

Figure 1. Chromium contents of earthworm body (mg.kg-1 fresh mass)

Table 6. Values of degree of contamination indices (C) for plants cultivated in experiment

Treatment		Maize – 1st year		
		Cob	Steam + leaves	Roots
Soil with addition of	Control (no fertilization)	-*	1.34	1.01
	FYM	0.73	1.21	1.20
	Tannery sludge (unprocessed)	0.93	0.78	1.49
	Vermicompost (tann. sludge + sawdust)	0.86	1.45	1.96
	Vermicompost (tann. sludge + cardboard)	0.67	0.66	2.06
	Vermicompost (tann. sludge + straw)	0.60	2.51	1.74
SD		0.14	0.66	0.42
VC%		18	50	27
Treatment		Rape – 2nd year		
		Top parts		Roots
Soil with addition of	Control (no fertilization)	0.34		1.43
	FYM	0.65		1.24
	Tannery sludge (unprocessed)	0.29		2.86
	Vermicompost (tann. sludge + sawdust)	0.27		2.20
	Vermicompost (tann. sludge + cardboard)	0.16		2.01
	Vermicompost (tann. sludge + straw)	0.11		1.62
SD		0.19		0.59
VC%		63		31
Treatment		Sunflower – 2nd year		
		Top parts		Roots
Soil with addition of	Control (no fertilization)	4.84		2.86
	FYM	0.98		0.98
	Tannery sludge (unprocessed)	1.02		1.14
	Vermicompost (tann. sludge + sawdust)	0.76		1.77
	Vermicompost (tann. sludge + cardboard)	0.80		1.23
	Vermicompost (tann. sludge + straw)	0.82		0.96
SD		1.62		0.73
VC%		106		49
Treatment		Oat – 3rd year		
		Grain	Straw	Roots
Soil with addition of	Control (no fertilization)	0.95	0.98	0.23
	FYM	1.05	0.95	0.68
	Tannery sludge (unprocessed)	1.21	1.16	3.19
	Vermicompost (tann. sludge + sawdust)	1.05	1.31	1.80
	Vermicompost (tann. sludge + cardboard)	1.37	1.16	1.75
	Vermicompost (tann. sludge + straw)	1.42	1.16	1.75
SD		0.19	0.13	1.03
VC%		16	12	66

* absent of yield

sawdust) and vermicompost (tannery sludge + cardboard) - by over 13%. Also considerable (by over 5%), although the smallest increase in the biomass of aboveground plant parts was detected in the object treated with tannery sludge vermicompost and straw.

Obtained increases in maize root biomass in effect of applied vermicomposts (as compared with farmyard manure) ranged between 10 and 22% and were statistically significant. The greatest increase in plant root biomass was caused by fertilization with mineral salts (Table 3). In research carried out by Kopeć et al [24] the effect of tannery sludge of chemical and biological origin on maize biomass increase proved slightly lesser than mineral salt effect. The assessment of the influence of chromium supplied to the soil with tannery sludge and vermicompost on plants cannot refer only to the plant yield, but should also consider its content in plants. On the basis of research conducted by Czekała [6] it may be concluded that in aquaculture sit chromium caused a decline in plant yield, irrespective of its dose. On the other hand, according to the author quoted above, chromium introduction into the soil led to a significant increase in sunflower biomass in comparison with the control. Presented investigations also registered greater increase in sunflower biomass on vermicompost treatments in comparison with biomass quantity on mineral salt treatment [12].

Computed tolerance indices for maize (grown after organic material application to soil) were lower than one, both on treatment with an addition of farmyard manure and vermicomposts (Table 4). Values of computed parameter point to growth inhibition of both the root system and the aboveground parts of the analyzed plant under the influence of applied organic materials. The obtained results do not have to testify toxic effect of these substances. Most probably such plant response might result from nutrient deficiency, probably nitrogen, which was wholly applied in the form of organic materials (except for the mineral salt treatment),which made difficult the access to this component. Values of tolerance index (Ti) for the other plants were above one or approximated one, which corroborates a lack of toxic consequent effect of vermicomposts based on tannery sludges on produced plant biomass (Table 4).

Tannery sludge vermicomposts used for fertilization and also untreated sludge did not increase significantly chromium concentrations in plant aboveground part as compared with the control (Table 5). Apart from rape grown in soil with added mineral salts and manure, chromium content in plant aboveground parts did not exceed 1 $mg \cdot kg^{-1}$ of yield dry matter. Chromium absorbed by the cultivated plants was stored by them mainly in the roots systems. The greatest amounts of this element were found in the roots of maize and oats (Table 5). The obtained results do not point to greater chromium accumulation in plant aboveground parts on treatments with vermicompost supplement. Despite great concentration of this element in materials applied for fertilization, its content in plant aboveground parts, which may provide a source of animal fodder, was insufficient [13],which may be explained by a passive chromium uptake by plants depending on its bioavailability in soil. According to Kabata-Pendias and Pendias [19] and Czekała [6], chromium occurrence in sewage sludges, mostly in sparingly soluble forms and its easy reduction make this element generally hardly available to plants. Mechanisms of this process probably results from trivalent chromium ability to form complexes and chelates with cell wall components. This process, as reported by Czekała [6] limits chromium penetration into a cell and translocation to the aboveground organs, which would explain its low concentration in the aboveground parts of the analyzed plants.

Values of plant contamination index (C) presented in Table 6 on farmyard manure treatments and objects with vermicompost and untreated tannery sludge supplements were diversified and depended on plant species. The value of discussed parameter for chromium in plant aboveground parts generally was below one, except for oats grain and straw on all treatments, except the control (Table 6). Similar dependencies were found for plant root system (Table 6).

CONCLUSIONS

1. Chromium in composts and vermicomposts based on tannery sludges occurred in small quantities and easily soluble compounds.
2. Chromium concentrations in redworm biomass points to this metal accumulation in Eisenia fetida body tissues. This element content in redworm biomass was significantly positively correlated with its content in composts.
3. Chromium content in plants was diversified and on treatments was generally smaller than on mineral treatment or farmyard manure.
4. Chromium absorbed by plants was stored mainly in the root systems, and over the norm content of this element found in vermicomposts did not cause its excessive accumulation in plant biomass.

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